EXTREME HYDROLOGICAL EVENTS IN THE POLISH TATRA MTS. UNDER DIFFERENT AIR CIRCULATION PATTERNS

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Introduction

The Tatra Mts. is the highest mountain massif of the Western Carpathians spreading through southern Poland and northern Slovakia with maximum elevation of 2655 m a.s.l. (Gerlach). Their area amounts approximately 785 km^2, of which only 175 km^2 lies in Poland. It constitutes only 0.56% of the Polish territory and is the only part of the country of alpine high mountain landscape with very complicated geology and features typical for high mountain environment: climate and vegetation are vertically differentiated. The location of the Western Carpathians is noticeable and distinctive: they are forming a border between two areas with different strength of influences of the air masses advecting from the Atlantic Ocean or continental Asia. Climate of the Tatra Mts. is dominated by polar maritime air-masses from the west. Due to the high elevation of the massif, the amount of annual precipitation reaches almost 2000 mm at the highest elevations being the highest precipitation in Poland (Hess 1996). Therefore the Tatra Mts. may be considered as the water tower in local scale; besides the headwater of the Dunajec River – one of the largest tributaries of the Vistula River is located there.

The Tatra streams show a prolonged peak flow as a result of spring snowmelt being extended by summer rain. The first maximum occurs during melt-water period – usually from April to May, and the second one – during summer rains period – usually from June to August. Rivers represents the pluvial-nival or niaval-pluvial patterns of flow regime. Summer rainfalls and floods are more variable in occurrence, amount and intensity. Hydrological extreme processes are caused by short-term rain events resulting from the local weather conditions, i.e. mainly air masses convection. The highest daily precipitation reached 300 mm on 30 Julne 1970 (Cebulak, 1998-1999). The low flows occur during late autumn and in winter, usually from October to January (Chełmicki *et al.*, 1998-1999; Dobija 1981). Mean multiannual specific runoff is spatially differentiated and amounts from 20 to 104 dm^3·s·km^2 in the Tatras (Łajczak 1996). The highest values of specific runoff regards to karst catchments. Increase of maximum winter and summer discharges was stated in second half of XX century in the Tatra rivers (not statistically significant; Kasina at al. 2007).

Primary aim of this work is to analyze extreme hydrological events in the Polish Tatras and determine the role of air circulation factors causing these events. The special attention was paid to the analysis of the synoptic situations associated with the mentioned hydrologic events. Several atmospheric circulation classifications have been taken into considerations such as: local calendar developed by T. Niedźwiedź, objective approach carried out by Z. Ustrnul as well as European classification "Grosswetterlagen" (Hess, Brezowsky, 1977; Niedźwiedź , 2006).

Data, methodology, results

Extreme hydrological events were analysed for the following rivers: Czarny Dunajec, Biały Dunajec, Poroniec, Białka for the period 1971-1990. The analyzed basins are small: from 58.4 to 93.7 km^2 (Figure 1, Table 1).

The length of the analysed data sets depended on the data availability. The distribution of daily discharges for the whole observation period was used to calculate an estimator of extreme hydrological conditions Q_{Ex} (threshold value) and was counted according to the formula:

$$Q_{Ex} = Q_{1\%}$$

where:

$Q_{1\%}$ – discharge of probability exceeding $p = 1\%$.

Extreme hydrological event applied in this work was defined as a term when the threshold discharge Q_{Ex} was exceeded ($Q \geq Q_{Ex}$). The annual frequencies of days with discharge exceeding specified threshold $Q_{1\%}$ and number of cases (periods) with discharge exceeding were also analysed.

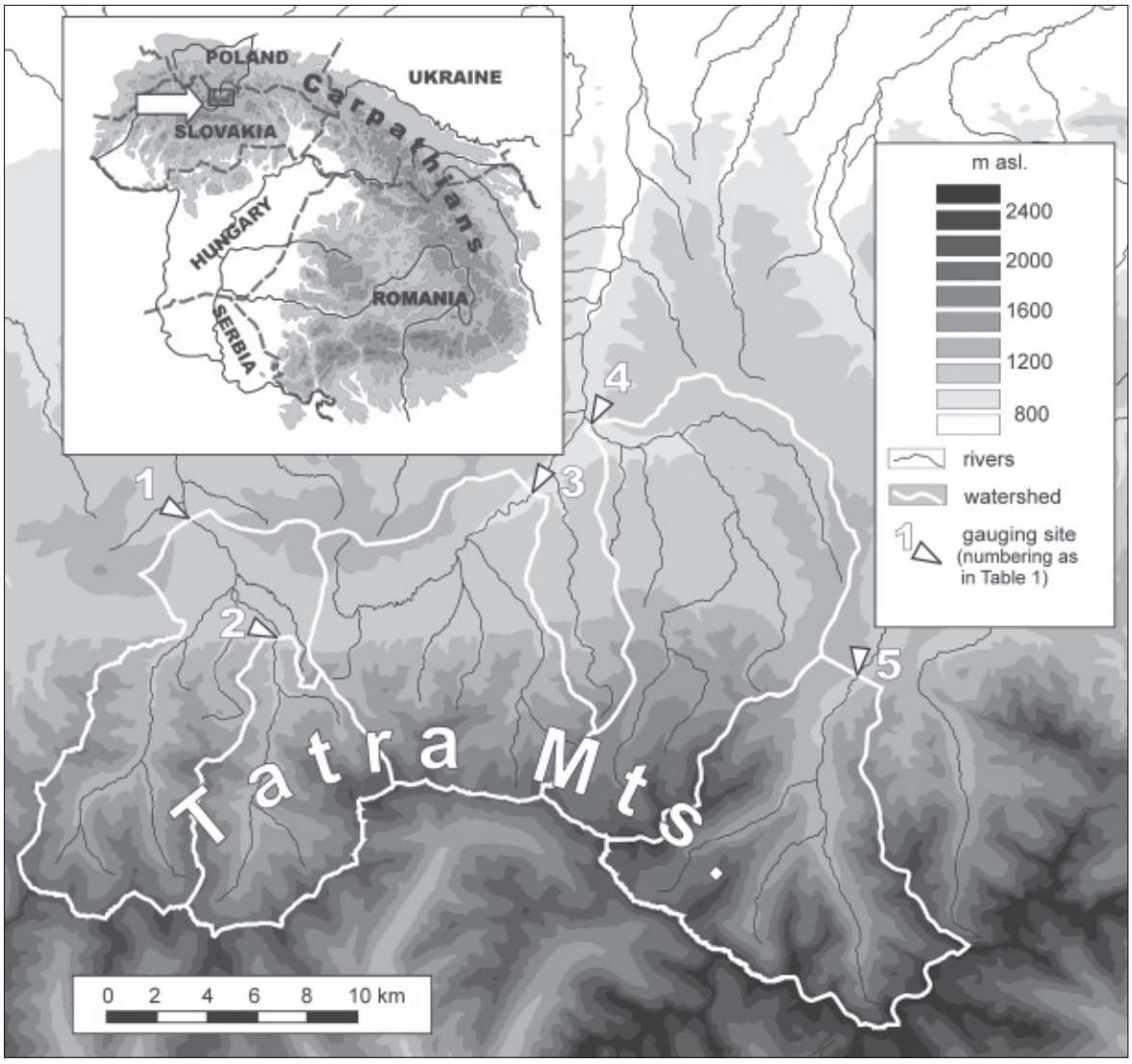

Figure 1. Research area

Table 1. Investigated catchments and their properties

No.	River – Gauging station	A (km^2)	Elevation of gauging station (m a.s.l.)	Maximum elevation (m a.s.l.)	Q 1% ($m^3 \cdot s^{-1}$)	Q max ($m^3 \cdot s^{-1}$)	Q max ($dm^3 \cdot s^{-1} \cdot km^{-1}$)	c_v
1	Czarny Dunajec – Kojsówka	93.7	837.7	2176	14.9	40.3	430.1	201.5
2	Kościeliski Stream – Kiry	34.5	920.8	2159	7.74	21.0	608.7	1050.0
3	Biały Dunajec – Harenda	58.4	763.1	2096	15.6	75.0	1284.3	340.9
4	Poroniec – Poronin	78.8	731.5	2301	9.9	69.5	882.0	992.9
5	Białka – Łysa Polana	63.1	965.6	2655	17.8	144	2282.1	654.6

Table 2. Number of days with river discharges $Q \geq Q_{1\%}$ in all analyzed catchments

Calendar year	winter (XII-III)	winter-spring (IV-VI)	summer (VII-VIII)	fall (IX-XI)	total	Calendar year	winter (XII-III)	winter-spring (IV-VI)	summer (VII-VIII)	fall (IX-XI)	Total
1971		6	2		8	1981		1			1
1972		1	4		5	1982	1	0	5		6
1973		2	5		7	1983		3	6		9
1974		9	2	3	14	1984		1		2	3
1975		5	2		7	1985		8	5		13
1976	1	5		3	9	1986		1			1
1977	1	2			3	1987		7			7
1978		4	6		10	1988		12	1	1	14
1979		0			0	1989	2	2	4	8	16
1980		4	14	6	24	1990		2		1	3
Total	2	38	35	12	87		3	37	21	12	73

Variability of a daily river runoff in Tatra Mts. is very high; the most dynamic is the smallest Kościeliski Stream, where variability coefficient c_v (the quotient of maximum and minimum daily discharges in the analysed period) amounts 1050.0 and the specific river maximum runoff amounts 608.7 $dm^3 \cdot s^{-1} \cdot km^{-1}$ (Table 1). The highest value of the specific river maximum runoff is at the Białka River and amounts 2282.1 $dm^3 \cdot s^{-1} \cdot km^{-1}$. The variability coefficient c_v is considerably much smaller than in the Kościeliski Stream and amounts 654.6 (Table 1). Four periods with large floods ($Q \geq Q_{1\%}$) has been distinguished: winter (XII-III), winter-spring (IV-VI), summer (VII-VIII) and autumn (IX-XI). Number of days with river discharge $Q \geq Q_{1\%}$ is the largest in the winter-spring meltwater period (Table 2).

Runoff in the Tatra Mts. in 1971-1990 was dominated by nival-pluvial flow regime. The analysis of extreme hydrological events and synoptic situations of local calendar developed by T. Niedźwiedź, Z. Ustrnul as well as "Grosswetterlagen" classifications has shown the strong linkage between circulation types and the river discharges exceeding $Q_{1\%}$. Extreme hydrological events in the Tatra Mts. catchments in almost all cases occurred during cyclonic N and NE air-advection which are mainly responsible for heavy rainfalls there.

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